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Sugawara

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(54) **IMAGE RECORDING APPARATUS AND IMAGE REPRODUCING APPARATUS**

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G03B 17/00 (2006.01)

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CPC ***H04N 5/23212*** (2013.01)

(58) **Field of Classification Search**
CPC H04N 5/23212; H04N 5/23229; H04N 13/0011; H04N 13/021; H04N 13/0217; H04N 13/0232; H04N 13/0418; H04N 1/0429; H04N 2201/02493; H04N 3/04; H04N 5/2254; H04N 5/23245; G02B 27/0075
USPC 348/345–347, 362–364, 356; 396/79, 396/82, 89
See application file for complete search history.

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Primary Examiner — Trung Diep
(74) *Attorney, Agent, or Firm* — Fitzpatrick, Cella, Harper & Scinto

(57) **ABSTRACT**

An image recording unit obtains image data which is obtained by a photographing operation, and can reconstruct a refocus image, and photographing information, generates a parameter used to reconstruct a refocus image in relation to an object included in an image based on the obtained photographing information, and records the generated parameter in a recording medium as meta data of the image data together with the obtained image data. An image reproducing apparatus reads out the recorded image data and parameter from the recording medium, reconstructs a refocus image from the readout image data using the readout parameter, edits the reconstructed refocus image according to an editing instruction, and edits a parameter of the edited refocus image.

30 Claims, 17 Drawing Sheets

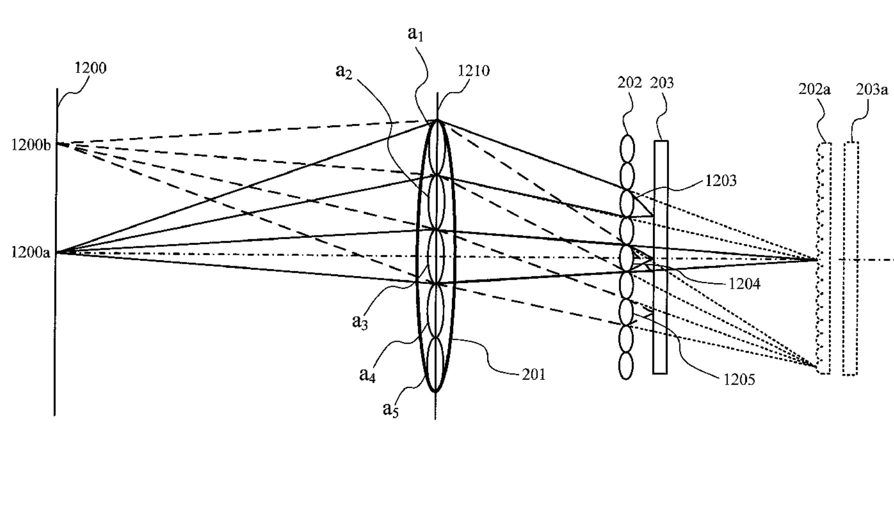

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FIG. 1

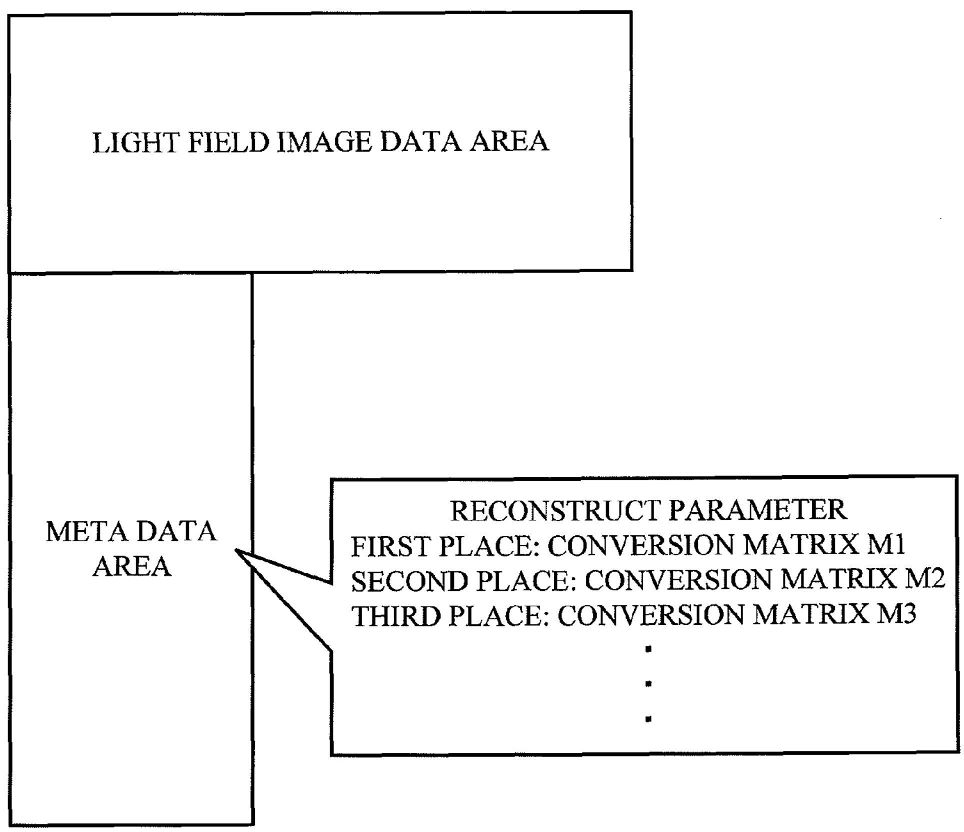

LIGHT FIELD IMAGE DATA AREA
META DATA AREA
RECONSTRUCT PARAMETER
FIRST PLACE: CONVERSION MATRIX M1
SECOND PLACE: CONVERSION MATRIX M2
THIRD PLACE: CONVERSION MATRIX M3

FIG. 2

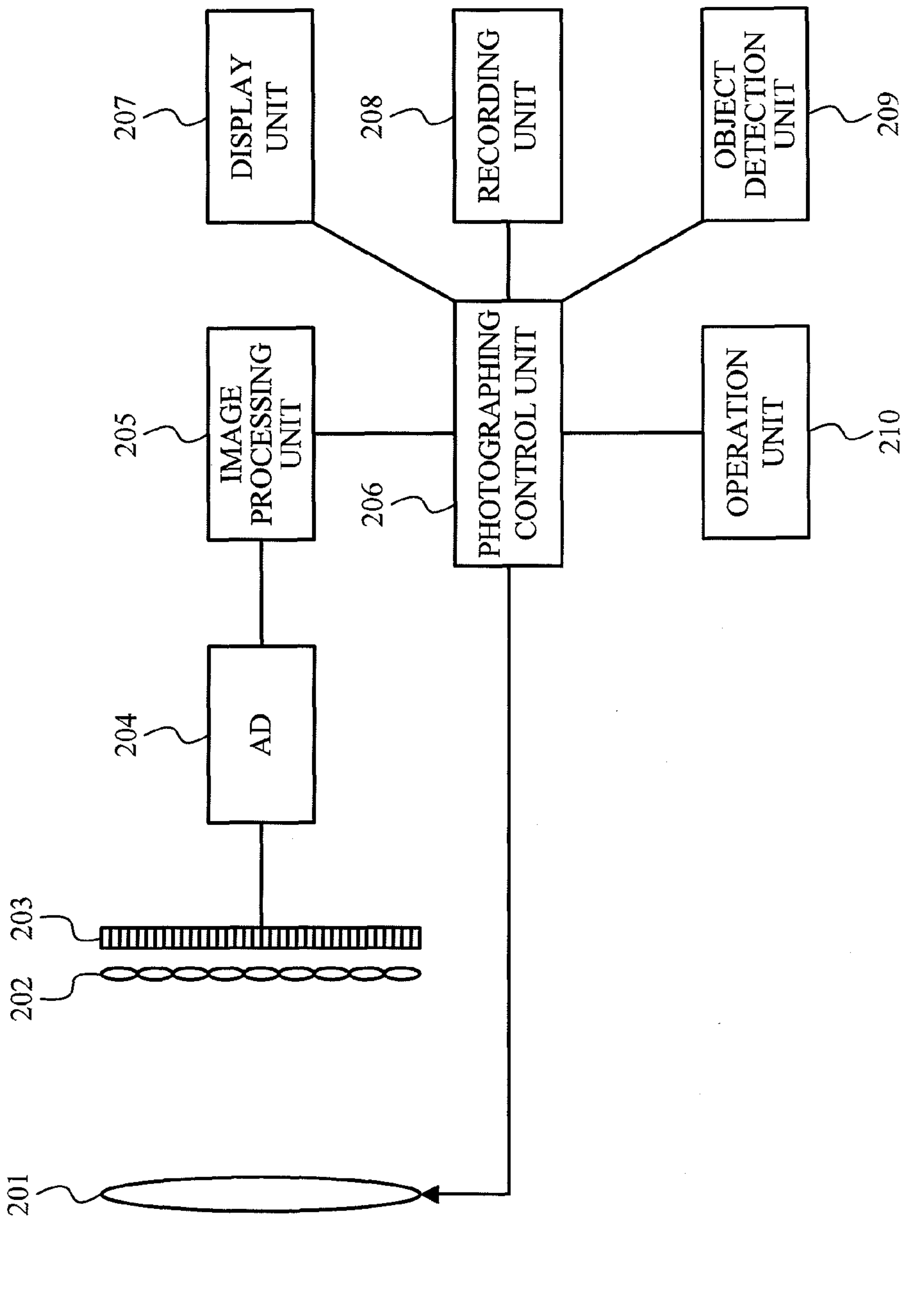

201
202
203
204
AD
205
IMAGE PROCESSING UNIT
206
PHOTOGRAPHING CONTROL UNIT
207
DISPLAY UNIT
208
RECORDING UNIT
209
OBJECT DETECTION UNIT
210
OPERATION UNIT

FIG. 3

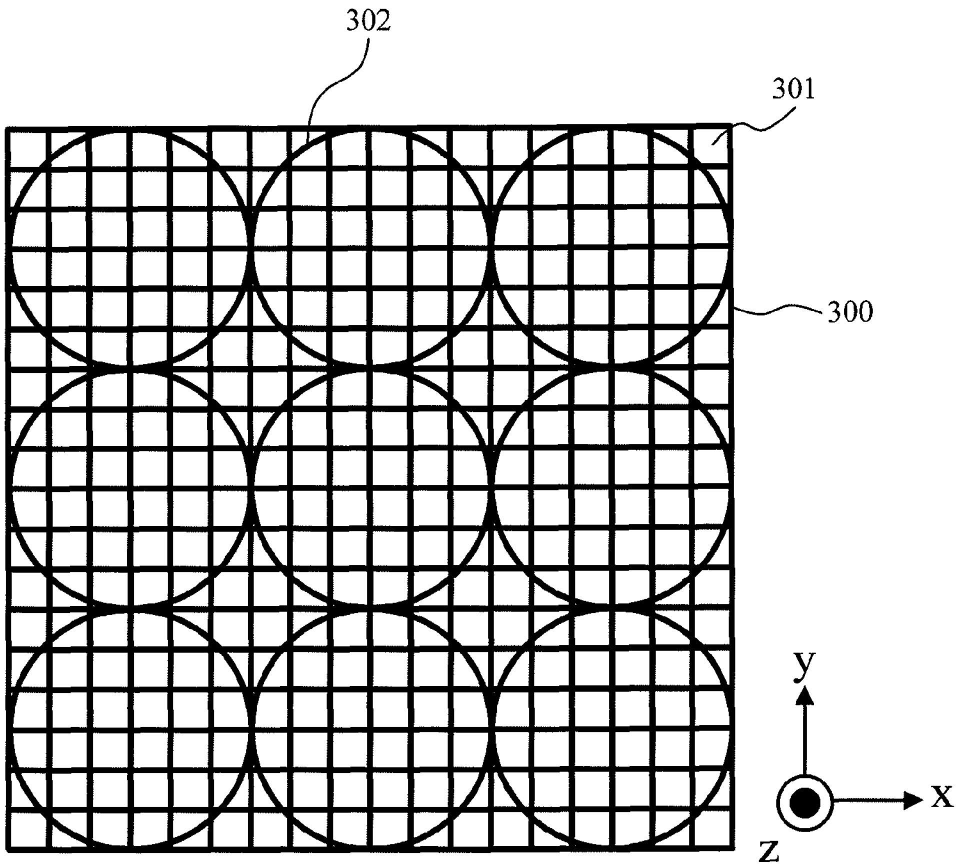


FIG. 4

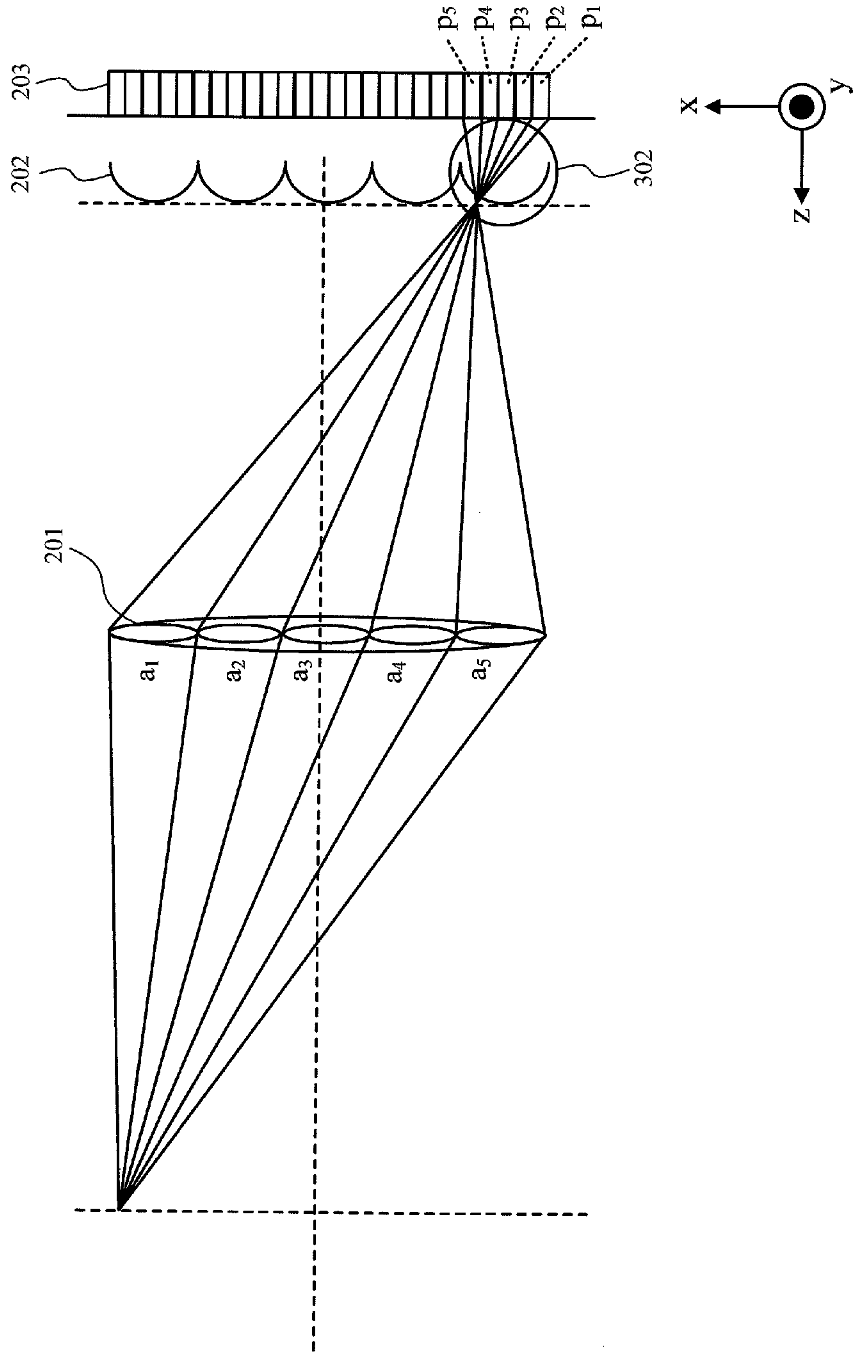


FIG. 5A

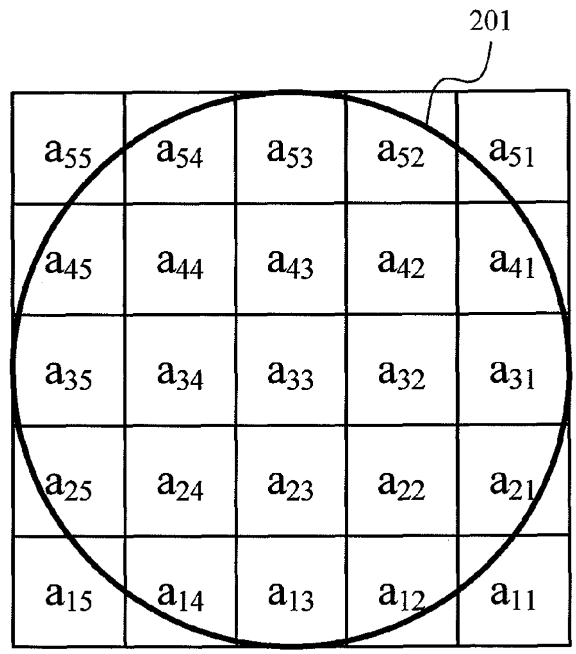

201
a55 a54 a53 a52 a51
a45 a44 a43 a42 a41
a35 a34 a33 a32 a31
a25 a24 a23 a22 a21
a15 a14 a13 a12 a11

FIG. 5B

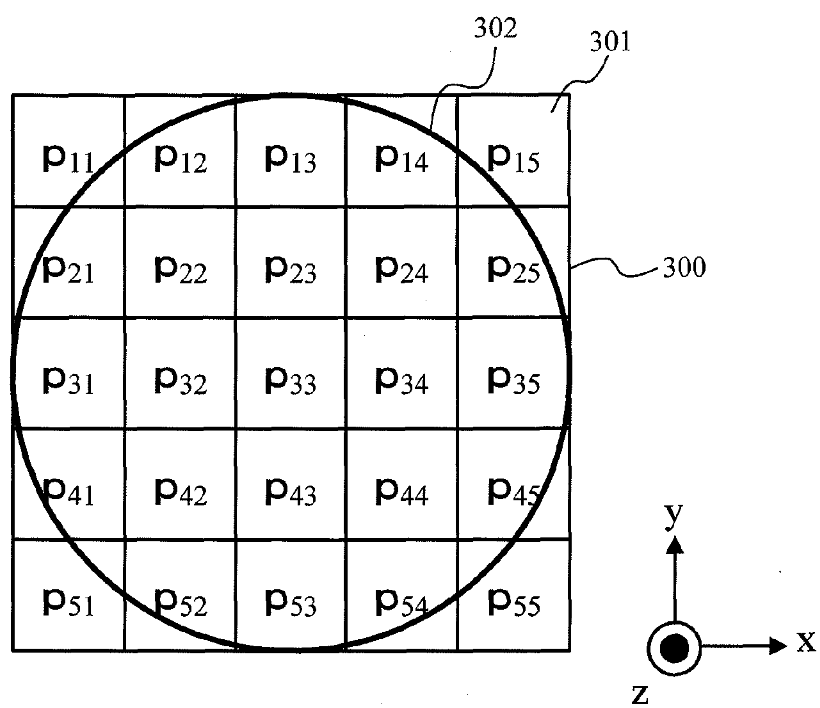

302
301
300
p11 p12 p13 p14 p15
p21 p22 p23 p24 p25
p31 p32 p33 p34 p35
p41 p42 p43 p44 p45
p51 p52 p53 p54 p55
y
x
z

FIG. 6A

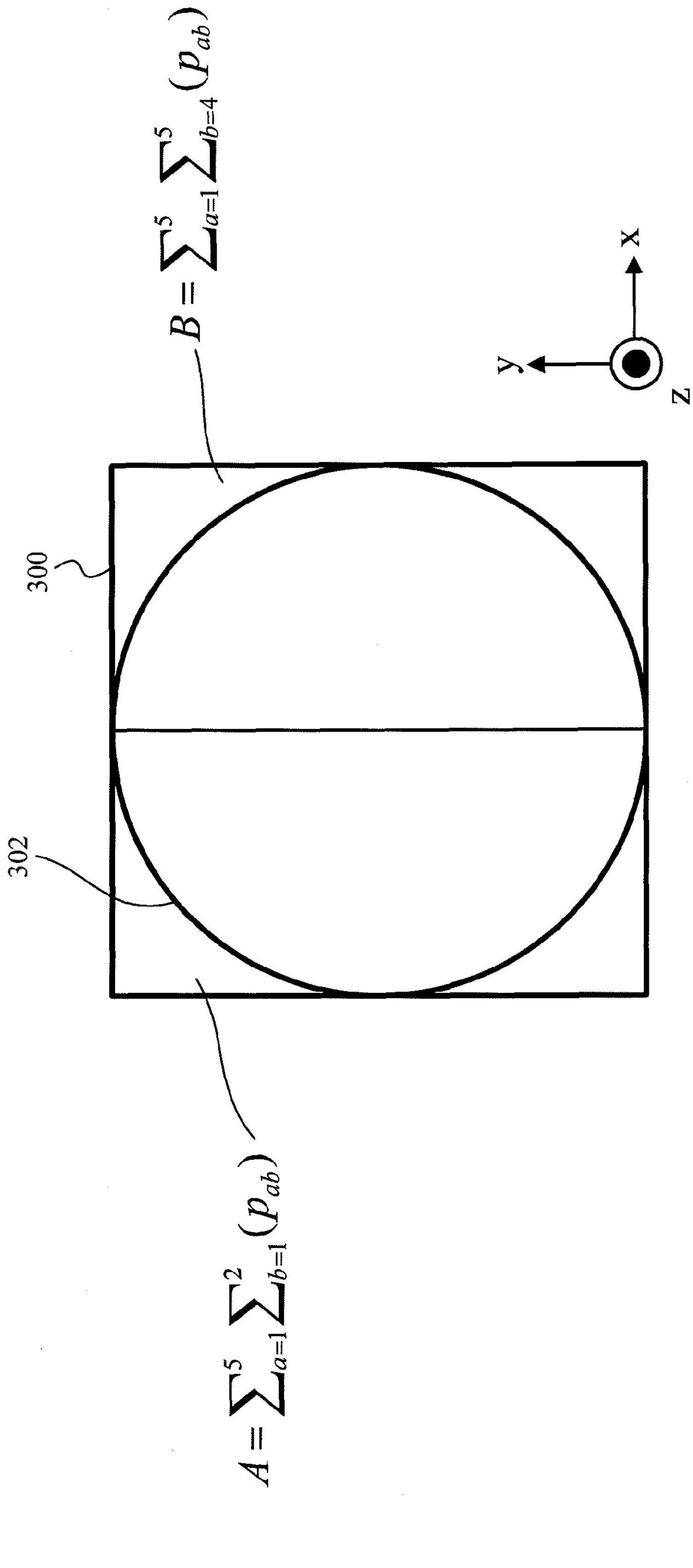


FIG. 6B

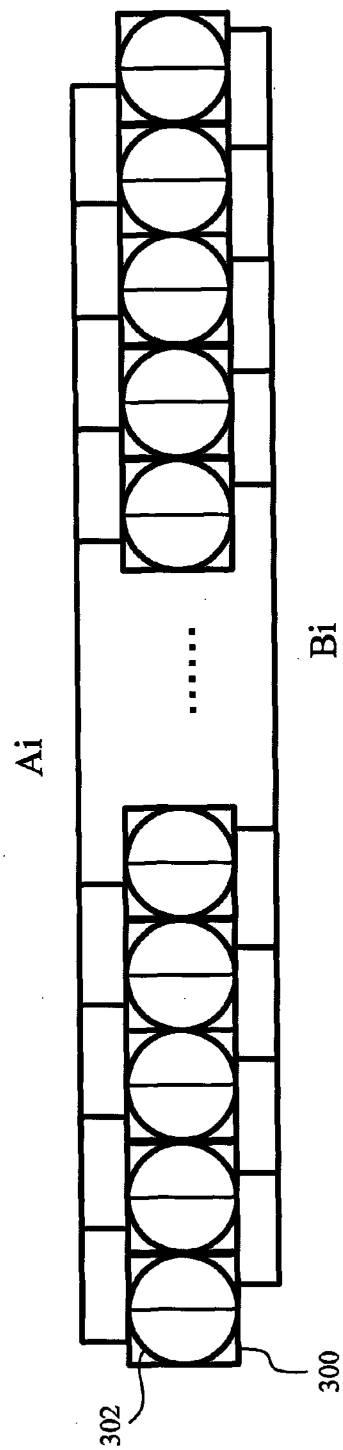
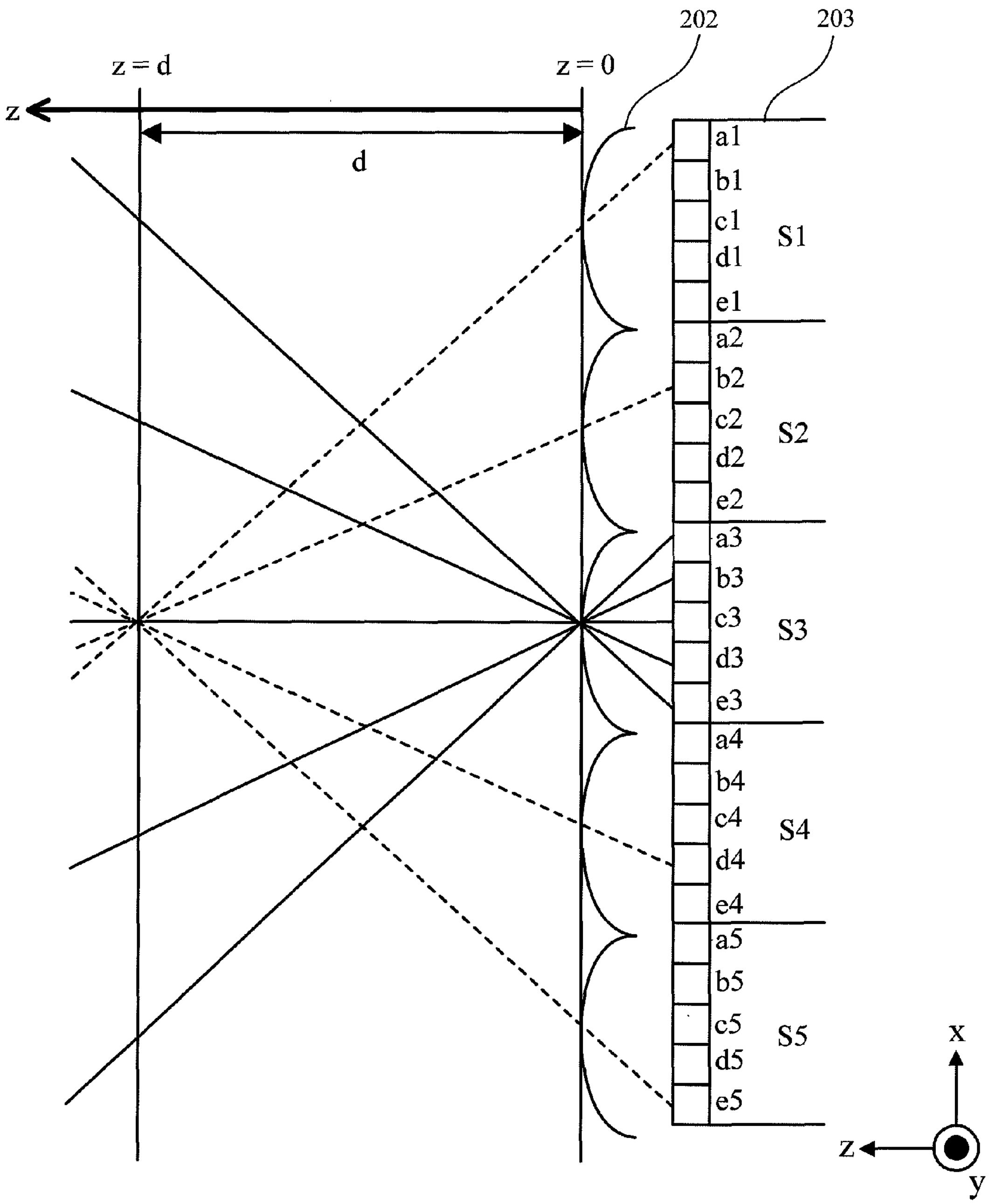


FIG. 7



202
203
z = d
z = 0
z
d
a1
b1
c1
d1
e1
S1
a2
b2
c2
d2
e2
S2
a3
b3
c3
d3
e3
S3
a4
b4
c4
d4
e4
S4
a5
b5
c5
d5
e5
S5
x
z
y

FIG. 8

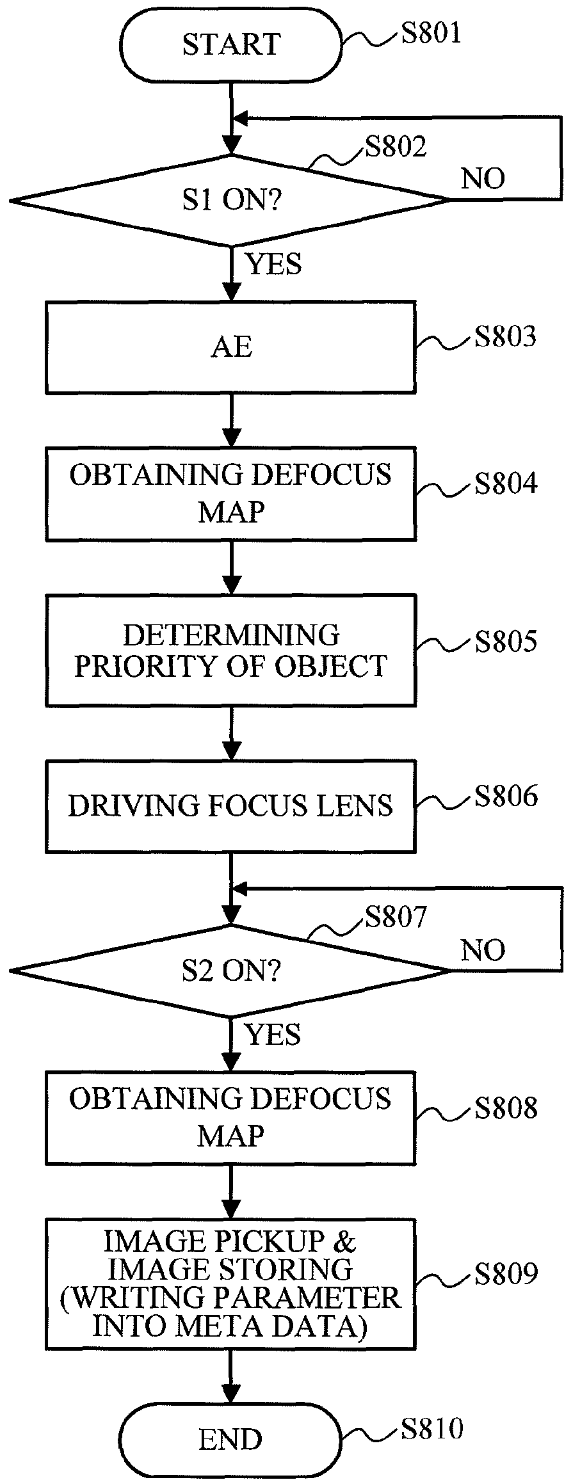

START
S801
S802
S1 ON?
NO
YES
AE
S803
OBTAINING DEFOCUS MAP
S804
DETERMINING PRIORITY OF OBJECT
S805
DRIVING FOCUS LENS
S806
S807
S2 ON?
NO
YES
OBTAINING DEFOCUS MAP
S808
IMAGE PICKUP & IMAGE STORING (WRITING PARAMETER INTO META DATA)
S809
END
S810

FIG. 9A

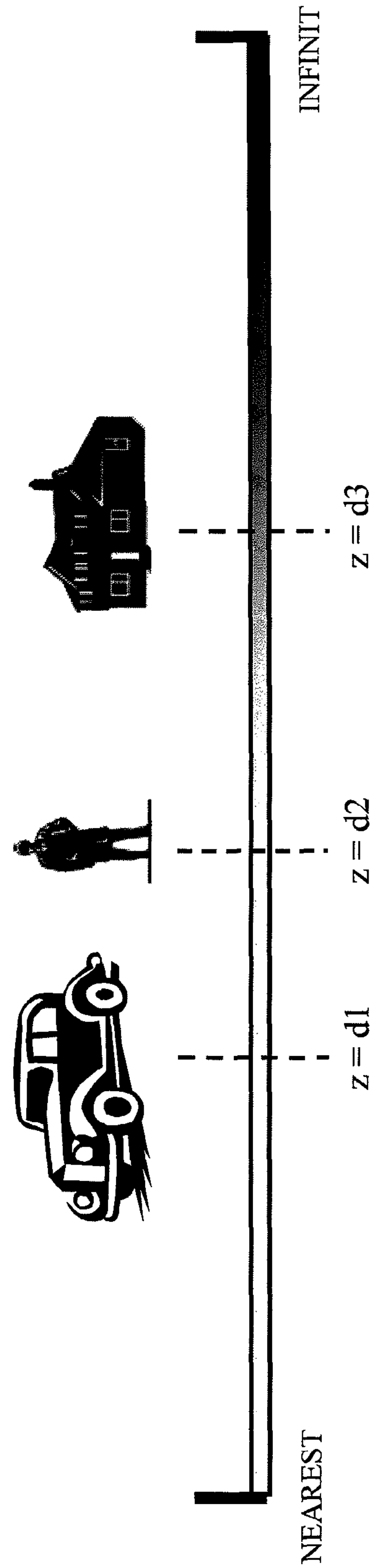
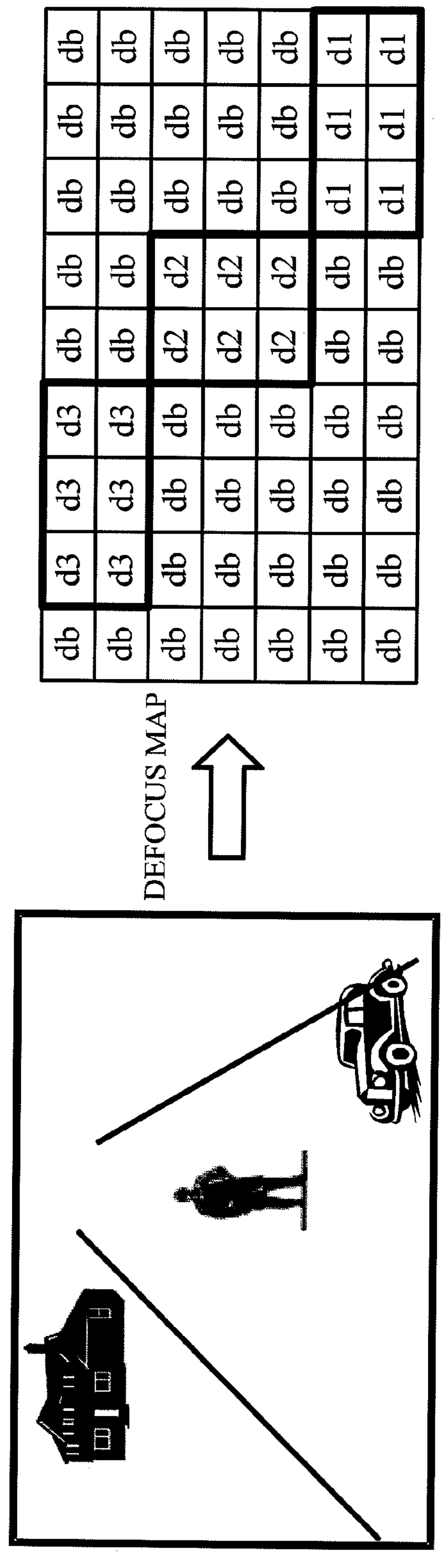


FIG. 9B



dbb	d33	d33	d33	dbb	dbb	dbb	dbb	dbb
dbb	d33	d33	d33	dbb	dbb	dbb	dbb	dbb
dbb	dbb	dbb	dbb	0	0	dbb	dbb	dbb
dbb	dbb	dbb	dbb	0	0	dbb	dbb	dbb
dbb	dbb	dbb	dbb	0	0	dbb	dbb	dbb
dbb	dbb	dbb	dbb	dbb	dbb	d11	d11	d11
dbb	dbb	dbb	dbb	dbb	dbb	d11	d11	d11

FIG. 9C

FIG. 10

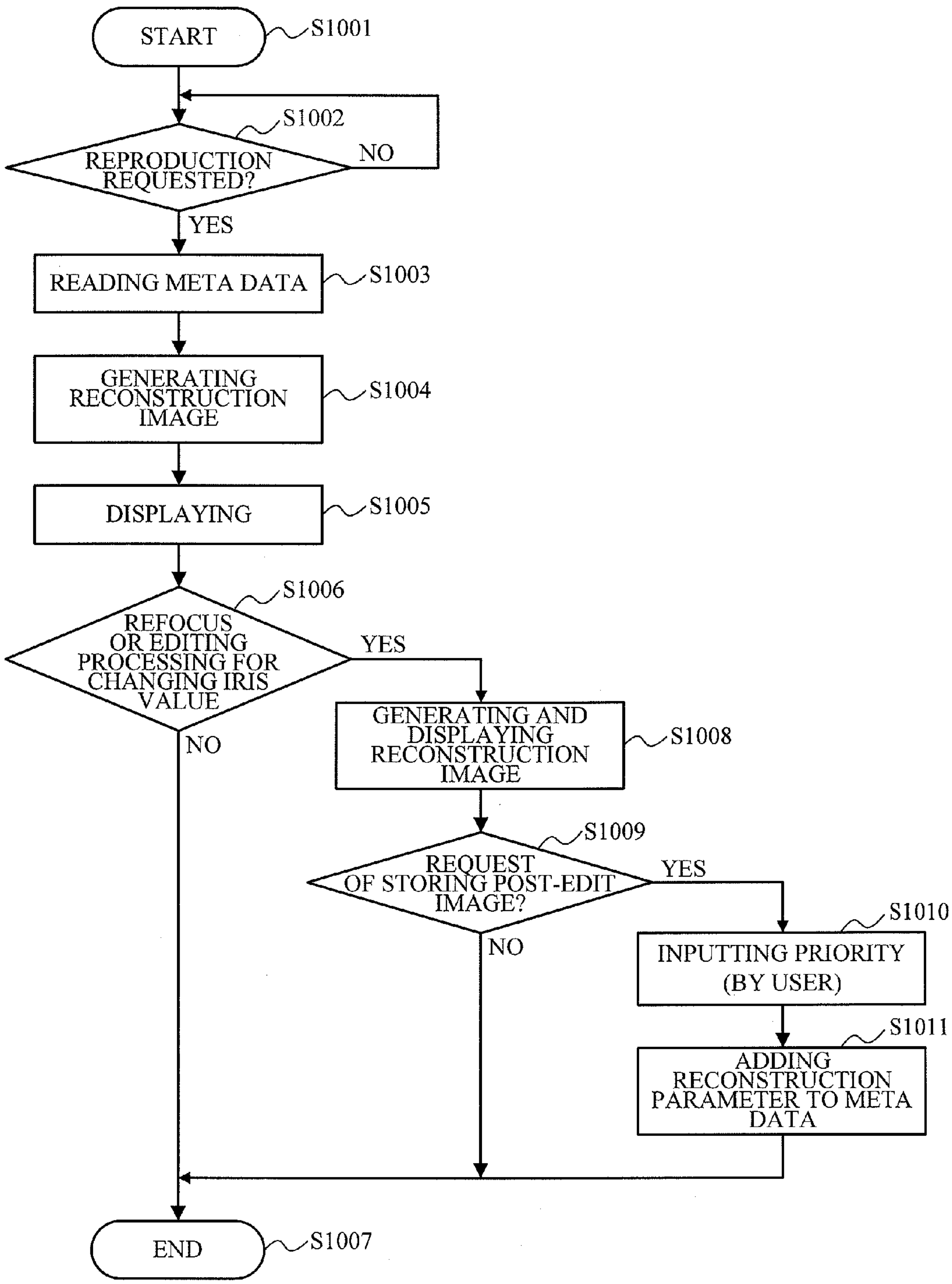

START
S1001
S1002
REPRODUCTION REQUESTED?
NO
YES
READING META DATA
S1003
GENERATING RECONSTRUCTION IMAGE
S1004
DISPLAYING
S1005
S1006
REFOCUS OR EDITING PROCESSING FOR CHANGING IRIS VALUE
YES
NO
GENERATING AND DISPLAYING RECONSTRUCTION IMAGE
S1008
S1009
REQUEST OF STORING POST-EDIT IMAGE?
YES
NO
S1010
INPUTTING PRIORITY (BY USER)
S1011
ADDING RECONSTRUCTION PARAMETER TO META DATA
END
S1007

FIG. 11

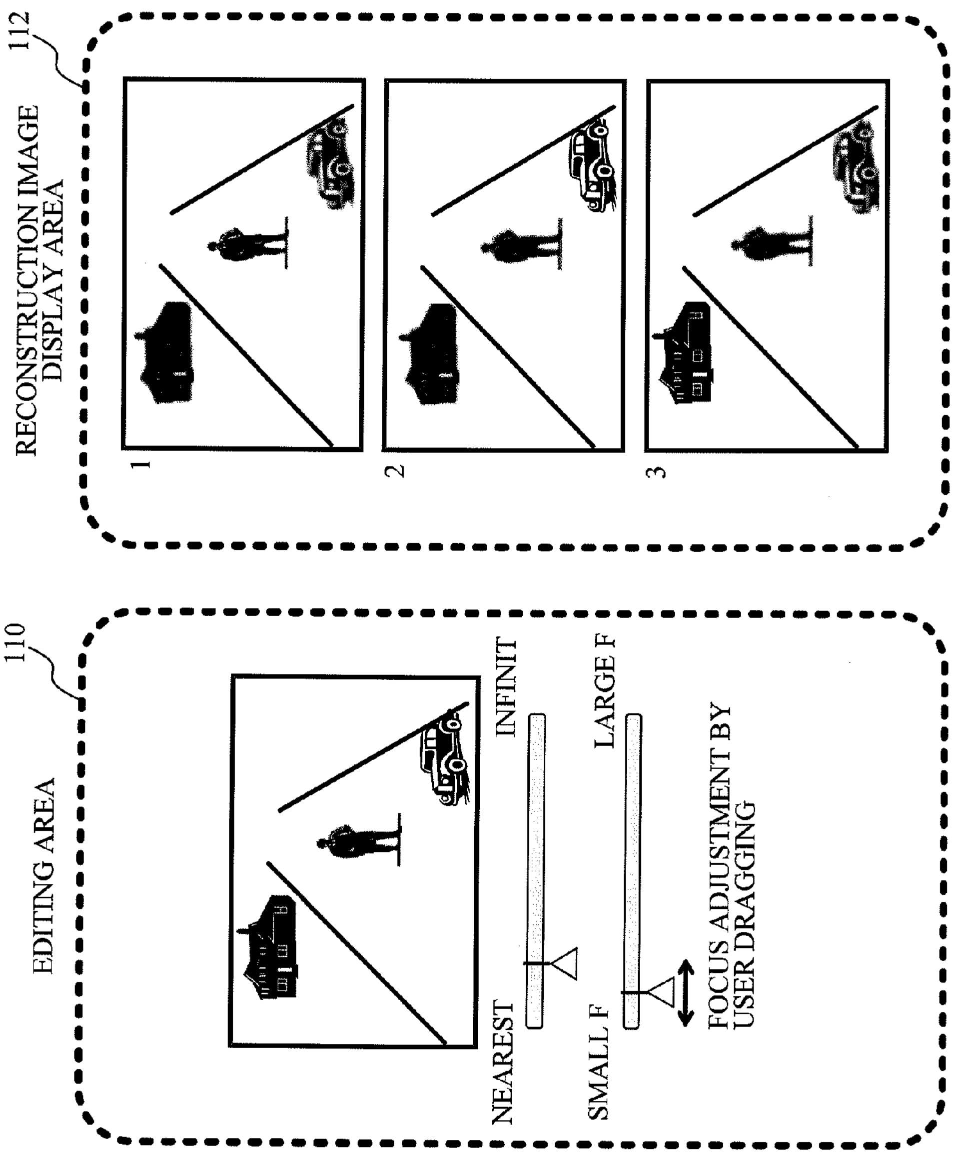

112
RECONSTRUCTION IMAGE DISPLAY AREA
1
2
3
110
EDITING AREA
NEAREST
INFINIT
SMALL F
LARGE F
FOCUS ADJUSTMENT BY USER DRAGGING

FIG. 12A

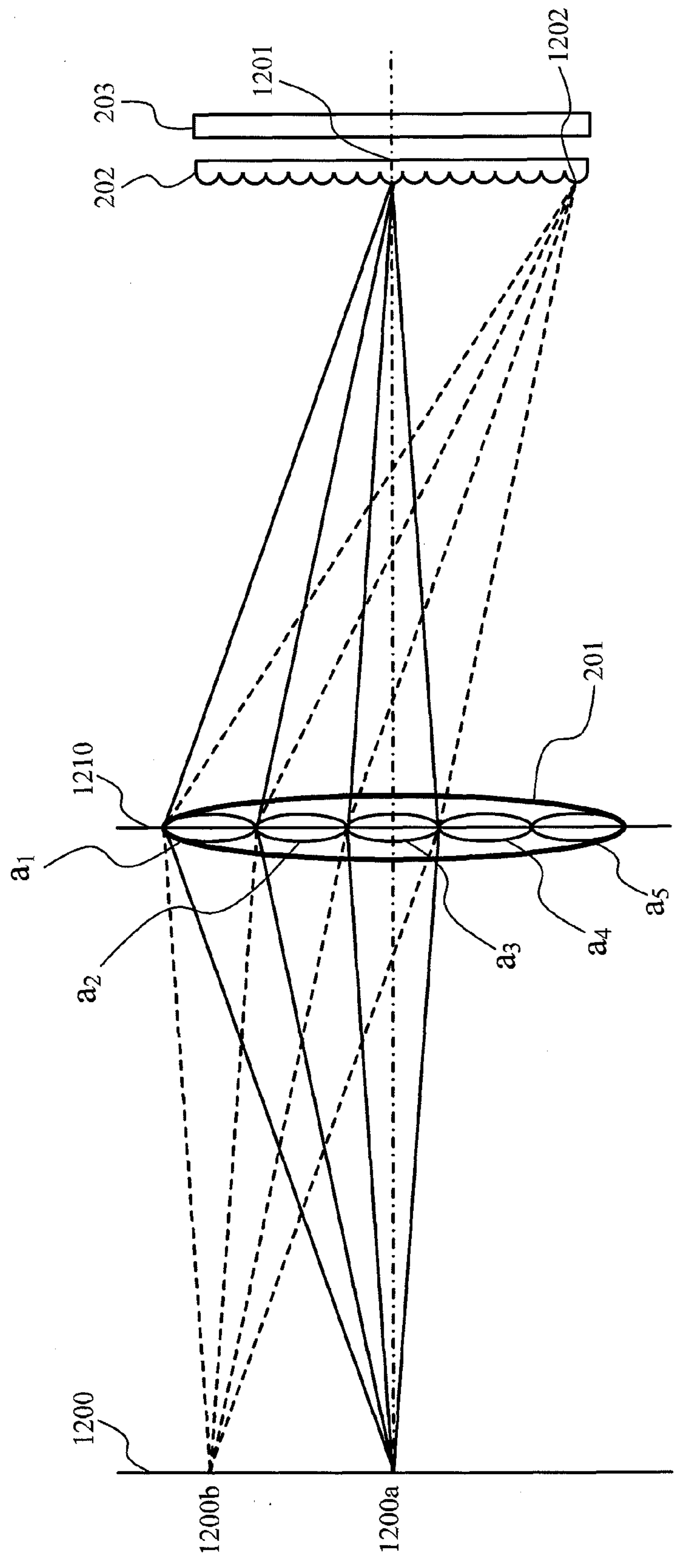


FIG. 12B

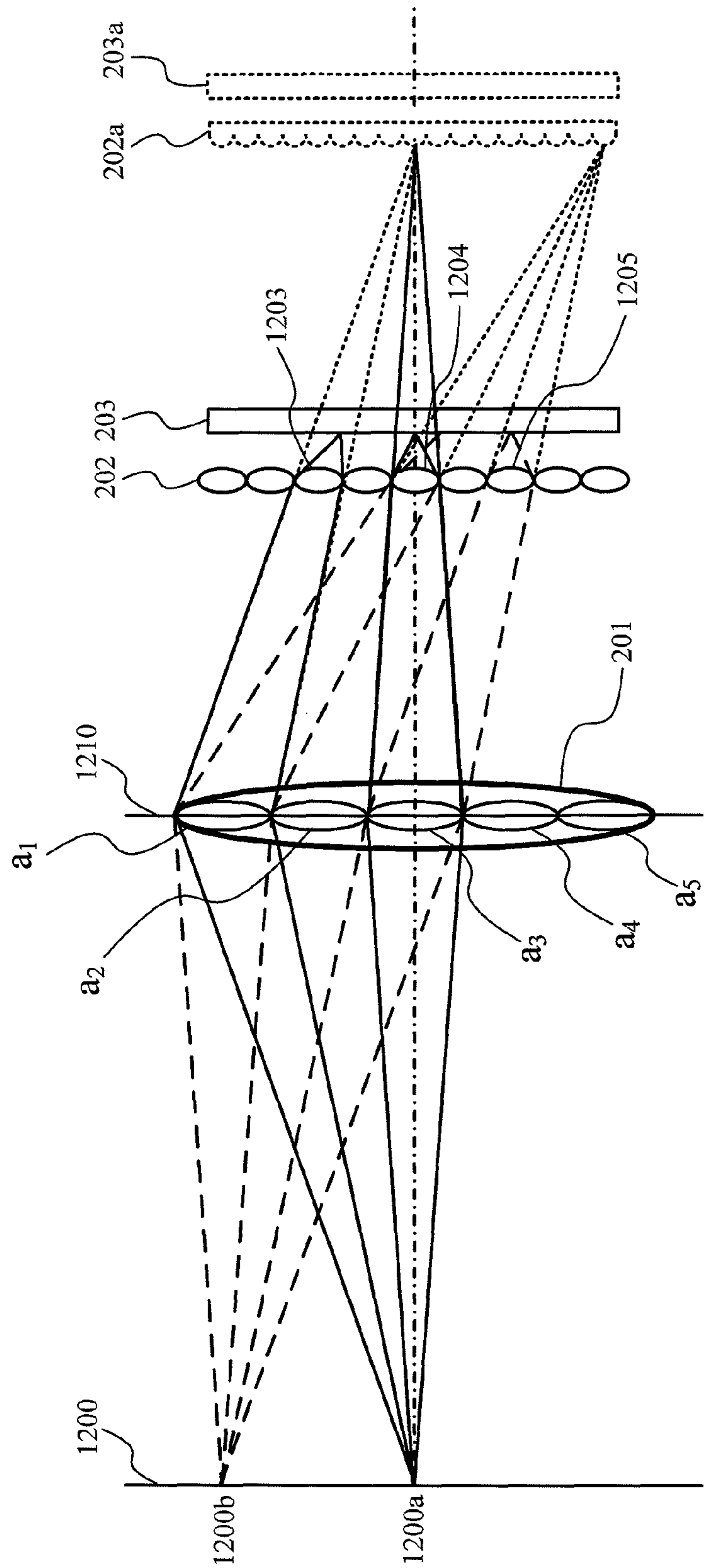

203a
202a
1203
1204
1205
203
202
201
1210
a_1
a_2
a_3
a_4
a_5
1200
1200b
1200a

FIG. 12C

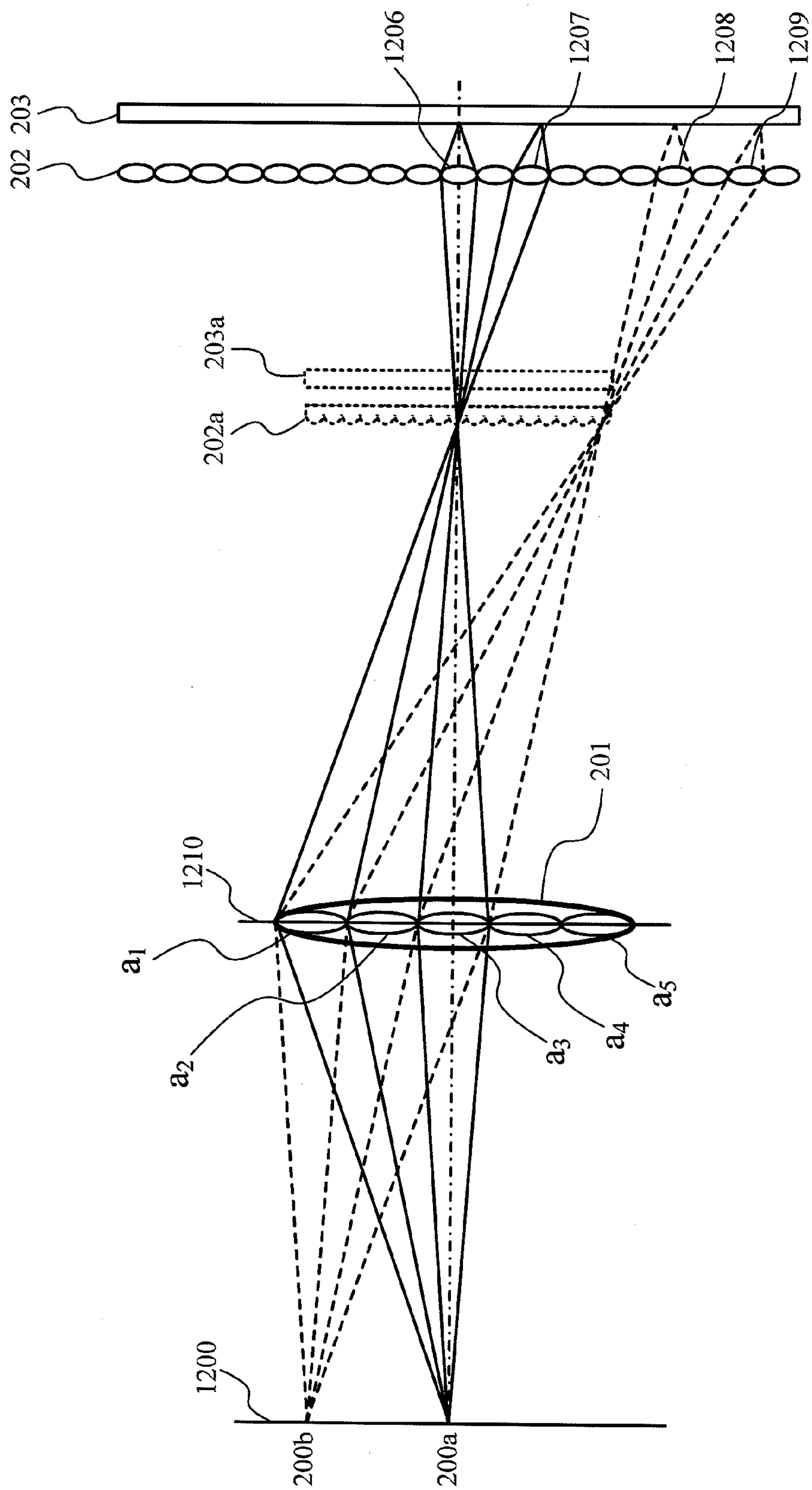

1206
1207
1208
1209
203
202
203a
202a
201
1210
a_1
a_2
a_3
a_4
a_5
1200
1200b
1200a

IMAGE RECORDING APPARATUS AND IMAGE REPRODUCING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an image pickup apparatus represented by a digital camera and, more particularly, to a recording apparatus of an image, which is photographed by an image pickup apparatus having a refocus function and a reproducing apparatus of the recorded image.

2. Description of the Related Art

In recent years, an image pickup apparatus arranged such that a microlens array including microlenses arranged at one to a plurality of pixels is arranged in front of an image pickup element so that information of incidence directions of rays of light incident on the image pickup element can be obtained in addition to pixel signals has been proposed by a non-patent literature (Ren. Ng and seven others, "Light Field Photography with a Hand-Held Planoptic Camera", Stanford Tech Report CTSR 2005-02) and the like. By using such image pickup apparatus, not only a normal photographed image based on output signals from respective pixels can be generated but also an image which is focused at an arbitrary focal length can be reconstructed by predetermined image processing is applied to a photographed image.

When such image that can be refocused is displayed for the purpose of browsing, it is difficult to judge at which a focus position an image to be displayed first is to be refocused. In order to solve this problem, a patent literature (Japanese Patent Application Laid-Open No. 2011-22796) extracts an object from an image, and displays a refocus image in which an area including that object is focused. Alternatively, image pickup conditions at the time of image are appended as tag data to image data, and a refocus image is generated based on that tag information.

However, the related art disclosed in the above patent literature requires processing for extracting an object before an image is displayed. Even in a case where information at the time of photographing is included as tag data, a phase difference between a plurality of images of different view points has to be calculated so as to determine a refocus plane after reconstruction, thus unwantedly generating arithmetic cost in either case.

SUMMARY OF THE INVENTION

An aspect of the present invention is to provide a recording apparatus and reproducing apparatus of image data, which can quickly display image data obtained by an image pickup apparatus that can photograph an object as an image that can be refocused, as a desired refocus image.

In order to solve the above-described problem, according to the invention, an image recording apparatus for recording image data from which a refocus image of an image including at least one object can be reconstructed, comprises: an obtaining unit configured to obtain image data which is obtained by photographing the image including at least one object and can reconstruct the refocus image, and photographing information of the image; a parameter generation unit configured to generate a parameter to be used to reconstruct the refocus image based on the obtained photographing information in relation to the object included in the image; and a recording unit configured to record the generated parameter as meta data of the image in a recording medium together with the obtained image data.

Furthermore, according to the present invention, an image reproducing apparatus for reproducing the image data recorded by the image recording apparatus, comprises: a read unit configured to read out the recorded image data and the parameter from the recording medium; a reconstruction unit configured to reconstruct a refocus image from the readout image data using the readout parameter; and an editing unit configured to edit the reconstructed refocus image according to an editing instruction, and to edit a parameter of the edited refocus image.

Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate exemplary embodiments, features, and aspects of the invention and, together with the description, serve to explain the principles of the invention.

FIG. **1** is a view showing the configuration of image data having reconstruction parameters in meta data.

FIG. **2** is a block diagram showing the arrangement of an image pickup apparatus to which a recording apparatus according to the first embodiment of the present invention is applied.

FIG. **3** is a view illustrating the arrangement of an image pickup element and microlens array used in the image pickup apparatus shown in FIG. **2**.

FIG. **4** is a conceptual view showing the arrangement of a photographing optical system including a photographing lens, microlens array, and image pickup element in the image pickup apparatus shown in FIG. **2**.

FIGS. **5**A and **5**B are views showing a correspondence relationship between a pupil area of the photographing lens of the image pickup apparatus shown in FIG. **2** and pixels of the image pickup element shown in FIG. **3**.

FIGS. **6**A and **6**B are views illustrating focus detection using outputs from the image pickup element and generation of signals required to detect a refocus plane.

FIG. **7** is a view showing the relationship between rays of light from different refocus planes and corresponding light-receiving pixels.

FIG. **8** is a flowchart of a recording operation according to the first embodiment of the present invention.

FIGS. **9**A, **9**B, and **9**C are conceptual views showing an image including a plurality of objects located at different distances and a defocus map of that image.

FIG. **10** is a flowchart of a reproducing operation of an image reproducing apparatus according to the second embodiment of the present invention.

FIG. **11** is a view illustrating a display screen of a reproduced image in the image reproducing apparatus according to the second embodiment of the present invention.

FIGS. **12**A, **12**B, and **12**C are conceptual views showing other optical systems applicable to an embodiment of the present invention.

DESCRIPTION OF THE EMBODIMENTS

Exemplary embodiments of the present invention will now be described in detail in accordance with the accompanying drawings.

First Embodiment

FIG. **2** is a block diagram of a digital camera as an image pickup apparatus to which an image recording apparatus according to the first embodiment of the present invention is applied. Reference numeral **201** denotes a photographing lens, which includes a plurality of lenses although not shown. The plurality of lenses include a movable focus lens, and a focus state with respect to an object can be adjusted by moving the focus lens. Reference numeral **202** denotes a microlens array (to be abbreviated as an MLA hereinafter), which includes a plurality of microlenses, and is arranged in the neighborhood of the focal point of the photographing lens **201**. Rays of light passing through different pupil areas of the photographing lens **201** are incident on the MLA **202**, and exit separately from the microlenses for every pupil division areas. Reference numeral **203** denotes an image pickup element, which includes a CCD, CMOS image sensor, or the like, and is arranged in the neighborhood of the focal point of the MLA **202**. Details of the MLA **202** and image pickup element **203** will be described later.

Reference numeral **204** denotes an AD converter, which AD-converts an image signal output from the image pickup element **203** into digital data. An image processing unit **205** applies predetermined image processing and the like to that digital data, thus obtaining digital image data of an object. Reference numeral **206** denotes a photographing control unit, which controls to display digital image data obtained by the image processing unit **205** on a display unit **207** including a liquid crystal display or the like, and to store the digital image data in a recording unit **208**. The photographing control unit **206** controls respective units when its CPU loads and executes a program stored in a memory (not shown). In this case, all or some of functions of the respective units may be implemented by the CPU or by hardware.

Reference numeral **209** denotes an object detection unit, which detects a face of a person from digital image data obtained by the image processing unit **205**, and detects a position and size of the face in its frame. An operation unit **210** includes buttons, a touch panel, and the like, which accept operations from the user, and performs various operations such as start of a focusing operation, and reproduction and deletion of digital image data stored in the recording unit **208** according to the accepted operations. The photographing lens **201** is electrically and mechanically connected to the photographing control unit **206**, which can obtain information of the photographing lens via communications, and can send a driving command and the like of the focus lens in case of a focusing operation.

The arrangement of the photographing lens **201**, MLA **202**, and image pickup element **203** in the image pickup apparatus shown in FIG. **2** will be described below.

FIG. **3** is a view for explaining the arrangement of the image pickup element **203** and MLA **202**. FIG. **3** shows the image pickup element **203** and MLA **202** when viewing from a z-direction parallel to an optical axis of the photographing lens **201**. One microlens **302** is arranged in correspondence with a plurality of unit pixels **301** (photoelectric conversion elements) which form a virtual pixel **300** of a photographed image. The microlens **302** is one of those which form the MLA **202**. FIG. **3** illustrates that a total of 25 (=5 rows×5 columns) unit pixels **301** correspond to one microlens. Coordinate axes appended to FIG. **3** define an optical axis direction as a z-axis, a plane perpendicular to the z-axis as a plane parallel to an image pickup plane, and an x-axis (horizontal direction) and y-axis (vertical direction) in the image pickup plane. Note that FIG. **3** partially shows a light-receiving surface of the image pickup element **203**, and a considerable number of pixels are arranged on an actual image pickup element.

FIG. **4** shows a state in which light exiting from the photographing lens **201** passes through one microlens **302** and is received by the image pickup element **203** when viewing from a direction perpendicular to an optical axis z. Rays of light exiting from respective pupil areas a_1 to a_5 of the photographing lens **201** and then passing through the microlens **302** are focused onto corresponding unit pixels p_1 to p_5 of the image pickup element **203**.

FIG. **5**A shows an aperture of the photographing lens **201** when viewing from the optical axis (z-axis) direction. FIG. **5**B shows one microlens **302** and the unit pixel **300** arranged behind that microlens when viewing from the optical axis (z-axis) direction. As shown in FIG. **5**A, when a pupil area of the photographing lens **201** is divided into areas as many as pixels located under one microlens, light coming from one pupil division area of the photographing lens **201** is focused onto one pixel. Assume that f-numbers of the photographing lens **201** and microlens nearly match in this case. Letting a_{11} to a_{55} be pupil division areas of the photographing lens shown in FIG. **5**A, and p^{11} to p_{55} be pixels shown in FIG. **5**B, their correspondence relationship is point-symmetric when viewing from the optical axis (z-axis) direction. Therefore, light exiting from the pupil division area a_{11} of the photographing lens is focused onto the pixel p_{11} of the pixels **301** located behind the microlens. Likewise, light exiting from the pupil division area a_{11} and then passing through another microlens is focused onto the pixel p_{11} of the pixels **301** located behind that microlens.

As described above, since the pixels p_{11} to p_{55} shown in FIG. **5**B receive rays of light passing through different pupil areas with respect to the photographing lens, a focus detection operation can be executed using outputs from these pixels. As shown in FIG. **6**A, pixel outputs p_{11} to p_{55} corresponding to respective microlenses are added to generate two signals, which are pupil-divided in the horizontal direction, as given by:

$$A = \sum_{a=1}^{5} \sum_{b=1}^{2} (P_{ab}) \tag{1}$$

$$B = \sum_{a=1}^{5} \sum_{b=4}^{5} (P_{ab}) \tag{2}$$

A combined signal A given by equation (1) views rays of light passing through areas a_1 and a_2 of an exit pupil of the photographing lens, as shown in FIG. **4**. When combined signals A_1 to A_n obtained from pixels corresponding to n microlenses, which are continuously arranged in the horizontal direction, are arranged, as shown in FIG. **6**B, a one-dimensional image signal A_i (i=1, 2, 3, . . . , n) is obtained. Likewise, when a one-dimensional image signal B_i (i=1, 2, 3, . . . , n) obtained by arranging combined signals B each calculated by equation (2) is also, generated, the signals A_i and B_i are those viewing respective right and left sides of the exit pupil of the photographing lens. For this reason, relative positions of the signals A_i and B_i are detected, and a focus detection operation based on a phase difference detection method can be executed according to a result obtained by multiplying their relative shift amount by a predetermined conversion coefficient. By generating the signals A_i and B_i at an arbitrary position in a frame, since a focus position at that position can be calculated, the focus lens is driven in accordance with the calculation result, thus attaining automatic focus adjustment.

Next, processing for reconstructing digital image data obtained by the photographing lens **201**, MLA **202**, and image pickup element **203** into an image at an arbitrarily set in-focus position (refocus plane) will be described below. FIG. **7** shows states of rays of light when a designated refocus plane is at z=0 and at z=d. In consideration of central pixels in FIG. **7**, when z=0, rays of light existing from the microlens are respectively incident on pixels a**3**, b**3**, c**3**, d**3**, and e**3**. Therefore, S**3** can be calculated as an output of a virtual pixel, as given by:

$$S3=a3+b3+c3+d3+e3 \tag{3}$$

The same applies to pixels such as S**1** other than S**3**.

When an image obtained by stopping down an iris of the lens is to be reconstructed, since light of only an area in the neighborhood of the center of the photographing lens according to an iris value need only be used, if S**3** is given by:

$$S3=b3+c3+d3 \tag{4}$$

a reconstruction image at z=0 when the iris is stopped down compared to the image given by equation (3) can be obtained. Furthermore, if S**3** is given by:

$$S3=c3 \tag{5}$$

an image at z=0 when the iris is further stopped down can be reconstructed. That is, an image in a stopping-down direction can be reconstructed.

Note that only five pixels arranged in an x-direction have been exemplified for the descriptive convenience. However since pixels are arranged on an x-y plane, the same idea applies two-dimensionally. For example, S**3** when the iris is open is given by the sum of 25 pixel outputs.

On the other hand, when z=d, since rays of light exiting from a plane at z=d are respectively incident on pixels a**1**, b**2**, c**3**, d**4**, and e**5**, S**3** can be generated, as given by:

$$S3=a1+b2+c3+d4+e5 \tag{6}$$

In this manner, when a position z (refocus position) of a refocus plane and an iris value F at the time of reconstruction are determined, a reconstruction image can be calculated. When this equation (6) is applied to other reconstructed pixels other than S**3**, a reconstruction image when z=d can be calculated by the following matrix calculations:

$$\begin{bmatrix} \ast \\ \ast \\ \ast \\ \ast \\ \ast \\ \ast \\ \ast \\ \ast \\ \ast \\ \ast \\ S1 \\ S2 \\ S3 \\ S4 \\ S5 \\ \ast \\ \ast \\ \ast \\ \ast \\ \ast \\ \ast \\ \ast \\ \ast \\ \ast \\ \ast \end{bmatrix} = \begin{bmatrix} \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast00100 & 00010 & 00001 & 00000 & 00000\ast\ast \\ \ast\ast01000 & 00100 & 00010 & 00001 & 00000\ast\ast \\ \ast\ast10000 & 01000 & 00100 & 00010 & 00001\ast\ast \\ \ast\ast00000 & 10000 & 01000 & 00100 & 00010\ast\ast \\ \ast\ast00000 & 00000 & 10000 & 01000 & 00100\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \\ \ast\ast\ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast & \ast\ast\ast\ast\ast\ast\ast \end{bmatrix} \begin{bmatrix} \ast \\ \ast \\ \ast \\ a1 \\ b1 \\ c1 \\ d1 \\ e1 \\ \\ a2 \\ b2 \\ c2 \\ d2 \\ e2 \\ \\ a3 \\ b3 \\ c3 \\ d3 \\ e3 \\ \\ a4 \\ b4 \\ c4 \\ d4 \\ e4 \\ \\ a5 \\ b5 \\ c5 \\ d5 \\ e5 \\ \ast \\ \ast \\ \ast \end{bmatrix} \tag{7}$$

That is, equation (7) means that if the position z of the refocus plane of a reconstruction image and the iris value F at the time of reconstruction are determined, the reconstruction image can be easily obtained by multiplying a matrix of all pixel outputs by M if preparing the following conversion matrix M is provided in advance:

$$M = \begin{bmatrix}
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,0\,0\,1\,0\,0 & 0\,0\,0\,1\,0 & 0\,0\,0\,0\,1 & 0\,0\,0\,0\,0 & 0\,0\,0\,0\,0\,*\,* \\
\,\,0\,1\,0\,0\,0 & 0\,0\,1\,0\,0 & 0\,0\,0\,1\,0 & 0\,0\,0\,0\,1 & 0\,0\,0\,0\,0\,*\,* \\
\,\,1\,0\,0\,0\,0 & 0\,1\,0\,0\,0 & 0\,0\,1\,0\,0 & 0\,0\,0\,1\,0 & 0\,0\,0\,0\,1\,*\,* \\
\,\,0\,0\,0\,0\,0 & 1\,0\,0\,0\,0 & 0\,1\,0\,0\,0 & 0\,0\,1\,0\,0 & 0\,0\,0\,1\,0\,*\,* \\
\,\,0\,0\,0\,0\,0 & 0\,0\,0\,0\,0 & 1\,0\,0\,0\,0 & 0\,1\,0\,0\,0 & 0\,0\,1\,0\,0\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,* \\
\,\,*\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,* & *\,*\,*\,*\,*\,*\,*
\end{bmatrix} \qquad (8)$$

A recording operation of this embodiment will be described below using the flowchart shown in FIG. **8**. In case of this embodiment, this operation is executed under the control of the photographing control unit **206** of the camera. After a camera operation is started in step S**801**, the control waits until the user turns on a switch S**1** as a pre-photographing preparation in step S**802**. The pre-photographing preparation includes AE/AF operations, and when the user operates an operation member included in the operation unit **210**, the switch S**1** is turned on. In this case, when the user half-depresses a two-step push button switch, the switch S**1** is turned on; when he or she full-depresses that switch, a switch S**2** is turned on. If the switch S**1** is turned on, the process advances to step S**803**.

In steps S**803** to S**806**, AE/AF operations as the pre-photographing preparation are executed. In step S**803**, an AE operation is executed. In the AE operation, an exposure level of an image is evaluated from output signal levels of the image pickup element **203** obtained under a predetermined condition, so as to determine an exposure condition which can prevent occurrence of saturation and blocked up shadows of output signals as much as possible. Note that as has already been described above, since a reconstruction image in a direction to increase an iris value (stopping-down direction) can be calculated according to equations (3) to (5), it is desirable to make a photographing operation under a condition in which the iris is opened as large as possible.

In steps S**804** to S**806**, the AF operation is executed. As has already been described using FIGS. **6**A and **6**B, the

camera shown in FIG. **2** can calculate a focus position at an arbitrary position in a frame. Hence, for example, when focus positions are detected for objects including a building, person, and vehicle which are distributed at different distances, as shown in FIG. **9**A, while dividing a frame into 63 (=9 (horizontal direction)×7 (vertical direction)) blocks, a defocus map shown in FIG. **9**B can be obtained. Note that in FIG. **9**B, a defocus amount of a portion corresponding to a background in the frame is indicated by db. In step S**804**, the defocus map is obtained in this way.

By grouping blocks having close defocus amount values for such defocus map, the number of objects can be roughly estimated. When the object detection unit **209** detects the presence of a face of a person in the frame, its position can be detected. Therefore, as can be seen from the example shown in FIGS. **9**A to **9**C, three objects are located at positions approximately corresponding to defocus amounts=d**1**, d**2**, and d**3**, and the object at the position d**2** is a person. Hence, this embodiment determines priorities for the object according to the following rules:

Priority 1: a face (when a plurality of faces are included, higher priorities are determined in descending order of size of the detected faces)

Priority 2: higher priorities are determined for objects other than a face in an order of the defocus amount from nearest to infinite

Upon application of these rules, in the example shown in FIGS. **9**A to **9**C, a person having the defocus amount=d**2** is set as an object with highest priority, a vehicle having the defocus amount=d**1**, which is not a face but is located at the nearest side, is set as an object with second highest priority, and a building having the defocus amount=d**3** is set as an object with third highest priority. In step S**805**, objects are specified from the defocus map, and priorities are set for the specified objects in this way. Note that this embodiment adopts the priority determination rules which prioritize a face of a person. However, these rules are a mere example, and the present embodiment is not limited to them. Alternatively, in place of or in preference to the priority determination rules, priorities may be manually determined using a switch or the like.

In step **S806**, in order to focus the person determined to have the highest priority by the priority determination, the focus lens is driven by the defocus amount=d**2**, thus completing the AF operation. Then, the control waits until the user turns on the switch S**2** in step S**807**. If the user turns on the switch S**2**, operations from step **S808** including a photographing operation are executed.

In step **S808**, an operation for obtaining a defocus map (photographing information) again immediately before the photographing operation is executed. Since the focus lens is driven to focus the person in step **S806**, when the defocus map is obtained at this timing, the defocus amount of the person portion becomes **0**, as shown in FIG. **9**C, and the defocus amounts of the vehicle portion and building portion are respectively changed to d**11** and d**33**. Note that a defocus amount of a portion corresponding to a background in the frame is indicated by dbb in FIG. **9**C.

After the defocus amounts of the respective objects are obtained, an image pickup operation is finally performed in step **S809**, and parameters required to obtain reconstruction images which are focused on the respective objects are generated and appended to the image pickup data as meta data. Assume that as for iris values of the reconstruction images, since that in the stopping-down direction can be changed later by the user, an iris value (photographing information) of parameters to be recorded at the time of photographing completion is F at the time of photographing. Also, conversion matrices M which can generate images focused on respective objects in a priority order determined in step S**805** are appended to the photographed image. That is, a conversion matrix M**1** (that required to generate a reconstruction image having a defocus amount=0 and iris value=F) which can reconstruct an image in which an object person is focused is appended as the first place of the priority. The second place is a conversion matrix M**2** (that required to generate a reconstruction image having a defocus amount=d**11** and iris value=F) which can reconstruct an image in which an object vehicle is focused. The third place is a conversion matrix M**3** (that required to generate a reconstruction image having a defocus amount=d**33** and iris value=F) which can reconstruct an image in which an object building is focused. As a result, these conversion matrices are appended as meta data of an image, as shown in FIG. **1**. Note that since each conversion matrix has a relatively large data size, only a position of a refocus plane (defocus amount) and iris value may be stored in meta data in a priority order. In this case, the defocus amount=0 and iris value=F for the first place, the defocus amount=d**11** and iris value=F for the second place, and the defocus amount=d**33** and iris value=F for the third place are appended to an image as parameters. After the photographed image data and the meta data required for refocusing, which is generated in association with the objects, as described above, are recorded, the photographing operation ends.

The recording apparatus of the present invention has been described taking, as an example, the image pickup apparatus as a digital camera. However, the present invention is not limited to this. For example, an arrangement in which image data and meta data are externally output from a camera and are recorded may be adopted. Also, an arrangement in which only image data and information for meta data are stored in a detachable-type recording medium at a time of photographing, and a processing apparatus such as a PC records the image data and meta data by executing face detection, priority determination, and assignment of tag data is available.

Second Embodiment

The first embodiment has explained the arrangement in which photographed image data is recorded while adding image reconstruction parameters to meta data. The second embodiment will explain an image reproducing apparatus which allows the user to browse image data which are recorded according to the first embodiment and can be reconstructed, and to perform editing operations for refocusing an image and changing an iris value. This embodiment will exemplify a case in which a PC having an interface shown in FIG. **11** displays and edits a reconstruction image by an application according to the flowchart shown in FIG. **10**. Assume that image data to be reproduced is that obtained by photographing objects shown in FIG. **9**A. As described in the first embodiment, this image is that appended as meta data of the image with a conversion matrix **M1** which can reconstruct an image in which an object person is focused as the first place, as shown in FIG. **1**. Likewise, this image data is appended, as the meta data of the image, with a conversion matrix M**2** which can reconstruct an image in which an object vehicle is focused as the second place, and a conversion matrix M**3** which can reconstruct an image in which an object building is focused as the third place.

FIG. **10** is a flowchart of an image reproducing operation according to the second embodiment. In this embodiment, as described above, this operation is attained when a CPU of the PC executes an application program to control respective units (for example, a display unit and the like) of the PC.

In step S**1002**, the control waits until the user inputs a reproduction request of image data which can be reconstructed. Then, when the reproduction request is input, the process advances to step S**1003**, and an image and its meta data corresponding to the reproduction request are obtained. In this case, the image data and meta data are those which are recorded by the recording apparatus according to the first embodiment, and are provided from the recording apparatus directly or via a detachable-type recording medium or the like.

The interface of the PC application shown in FIG. **11** is largely divided into right and left areas, and the right area is an area **112** for displaying a plurality of reconstruction images. In step S**1003**, reconstruction parameters in the meta data are read, and images which are reconstructed based on the read reconstruction parameters (conversion matrices M**1**, M**2**, and M**3**) are displayed in turn from the top in a priority order in steps S**1004** and S**1005**. In this case, a reconstruction image in which a person as an object with the highest priority is displayed at an uppermost position on the right area of a screen, a reconstruction image in which a vehicle as an object with the priority of the second place is focused is displayed below that image, and a reconstruction image in which a building as an object with the priority of the third place is focused is displayed at a lowermost position. Note that when the number of reconstruction images which can be displayed on the reconstruction image display area **112** is limited to n (for n≥1) in terms of a display space of the screen, reconstruction images based on top n conversion matrices stored in meta data are displayed on the display area.

After the reconstruction images based on the reconstruction parameters stored in the meta data are displayed, the process advances to step S1006 to wait for an editing instruction for refocusing an image or changing an iris value from the user. If no editing instruction is received in this step, the process advances to step S1007 to end the sequence. On the other hand, if the editing instruction is received, the following operation is performed. That is, the left area of FIG. 11 is an editing area 110 which displays an image during editing. The editing area displays a reproduced image and an interface used to edit a refocus plane and iris value. When the user drags two gauges to the right or left, he or she can instruct to change the refocus plane and iris value. Every time each gauge is operated, a conversion matrix required to generate a reconstruction image corresponding to the gauge is calculated, and a post-edit reconstruction image is generated and displayed in step S1008. Thus, an image which reflects user instructions can be displayed.

When the user edits the refocus plane and iris value and then wants to store post-edit reconstruction images, he or she issues a post-edit image storage instruction in step S1009. If the storage request is received, the control prompts the user to also input (set) priorities of the post-edit images, and conversion matrices generated in step S1008 are added to meta data of the image data in step S1011. At the same time, the post-edit images are displayed at positions according to the priorities on the reconstruction mage display area 112 in FIG. 11, thus ending the operation of this embodiment.

For example, assume that a reconstruction image in which a person is focused, and which image is stored as the first place of the priority in the meta data at the beginning of image reproduction, is strictly an image in which ears of a person are focused. Then, assume that the user reconstructs an image in which eyes of a person are focused by editing, and stores this conversion matrix as the first place of the priority. In this case, since the reconstruction image in which the eyes of the person are focused is set as the first place of the priority, the priorities of reconstruction images originally stored in the meta data are shifted down one by one. As a result, the second place of the priority is the image in which the ears of the person are focused, the third place of the priority is the image in which the vehicle is focused, and the fourth place of the priority is the image in which the building is focused. Note that when the user replaces an arranging order of images or deletes a image on the reconstruction image display area 112, the priorities may be changed. In this case, latest priorities are re-calculated in synchronism with the replacement or deletion, and reconstruction image generation conversion matrices written into the meta data are also rewritten in correspondence with the priorities after re-calculations.

Note that this embodiment has exemplified the reproducing and editing operations of image data by means of the application at the PC. However, an embodiment of the present invention is not limited to this. For example, a CPU of the photographing control unit 206 of the image pickup apparatus according to the first embodiment may execute a program to control respective units such as the display unit 207, thereby implementing a reproducing operation. Also, the present invention can also be implemented as an image processing function in an apparatus having a display function other than the PC.

According to the aforementioned first and second embodiments of the present invention, image data which can quickly reconstruct and display a refocus image in a desired focus state can be provided as recording data, and the possibility of efficient use of that image data can be extended.

Examples of other optical systems applicable to this embodiment will be described below with reference to FIGS. 12A to 12C. FIGS. 12A to 12C illustrate a state in which rays of light coming from an object are focused onto the image pickup element 206. The example shown in FIG. 12A corresponds to the optical system described using FIGS. 2 to 4, and the MLA 202 is arranged in the neighborhood of a focus plane of the photographing optical system. FIG. 12B shows an example in which the MLA 202 is arranged at a position closer to an object than the focus plane of the photographing optical system. FIG. 12C shows an example in which the MLA 202 is arranged on a side farther from an object than the focus plane of the photographing optical system. In FIGS. 12A to 12C, the same reference numerals denote the same parts as those shown in the already described drawings.

In FIGS. 12A to 12C, reference numeral 1200 denotes an object plane; and 1200*a* and 1200*b*, appropriate points on an object. Reference symbols denote a_1 to a_5, areas of a pupil plane of the photographing optical system. Reference numerals 1201 to 1209 denote specific microlenses on the MLA. In FIGS. 12B and 12C, reference numeral 203*a* denotes a virtual image pickup element; and 202*a*, a virtual MLA. These are illustrated for the purpose of reference so as to clearly specify correspondence relationships with FIG. 12A. Also, rays of light exiting from the point 1200*a* on the object and then passing through the areas a_1 and a_3 on the pupil plane are illustrated by the solid lines, and rays of light exiting from the point 1200*b* on the object and then passing through the areas a_1 and a_3 on the pupil plane are illustrated by the broken lines.

In the example shown in FIG. 12A, since the MLA 203 is arranged in the neighborhood of the focus plane of the photographing optical system, the image pickup element 203 and a pupil plane 1210 of the photographing optical system have a conjugate relationship. Furthermore, the object plane 1200 and MLA 202 have a conjugate relationship. For this reason, rays of light exiting from the point 1200*a* on the object reach the microlens 1201, those exiting from the point 1200*b* reach the microlens 1202, and the rays of light respectively passing through the areas a_1 to a_5 respectively reach corresponding pixels arranged under the microlens.

In the example shown in FIG. 12B, rays of light coming from the photographing optical system are focused by the MLA 202, and the image pickup element 203 is arranged on that focus plane. With this arrangement, the object lane 1200 and image pickup element 203 have a conjugate relationship. Light exiting from the point 1200*a* on the object and then passing through the area a_1 on the pupil plane reaches the microlens 1203, and light exiting from the point 1200*a* on the object and then passing through the area a_3 on the pupil plane reaches the microlens 1204. Light exiting from the point 1200*b* on the object and then passing through the area a_1 on the pupil plane reaches the microlens 1204, and light exiting from the point 1200*b* on the object and then passing through the area a_3 on the pupil plane reaches the microlens 1205. Rays of light passing through each microlens reaches corresponding pixels arranged under that microlens. In this manner, rays of light are respectively focused onto different positions depending on the points on the object and the passing areas on the pupil plane. When they are re-arranged on the virtual image pickup plane 203*a*, the same information as in FIG. 12A can be obtained. That is, information of the passing pupil areas (incidence angles) and positions on the image pickup element can be obtained.

In the example of FIG. **12**C, rays of light coming from the photographing optical system are re-converged by the MLA **202** (they are "re-converged" since once focused rays of light in a diffusing state are focused again), and the image pickup element **203** is arranged on its focus plane. With this arrangement the object plane **1200** and image pickup element **203** have a conjugate relationship. Light exiting from the point **1200***a* on the object and then passing through the area a_1 on the pupil plane reaches the microlens **1207**, and light exiting from the point **1200***a* on the object and then passing through the area a_3 on the pupil plane reaches the microlens **1206**. Light exiting from the point **1200***b* on the object and then passing through the area a_1 on the pupil plane reaches the microlens **1209**, and light exiting from the point **1200***b* on the object and then passing through the area a_3 on the pupil plane reaches the microlens **1208**. Rays of light passing through each microlens reaches corresponding pixels arranged under that microlens. As in FIG. **12**B, when they are re-arranged on the virtual image pickup plane **203***a*, the same information as in FIG. **12**A can be obtained. That is, information of the passing pupil areas (incidence angles) and positions on the image pickup element can be obtained.

FIGS. **12**A to **12**C have exemplified the case in which the MLA (phase modulation element) is used as a pupil division unit to obtain position information and angle information. Alternatively, other optical arrangements may be used as long as position information and angle information (equivalent to restrictions of pupil passing areas) can be obtained. For example, a method of inserting a mask (gain modulation element) with an appropriate pattern into an optical path of the photographing optical system can also be used.

According to the present invention described above, a recording apparatus of image data which can quickly display a refocus image of a desired focus state and a reproducing apparatus of the recording data can be provided.

Other Embodiments

Embodiments of the present invention can also be realized by a computer of a system or apparatus that reads out and executes computer executable instructions recorded on a storage medium (e.g., non-transitory computer-readable storage medium) to perform the functions of one or more of the above-described embodiment(s) of the present invention, and by a method performed by the computer of the system or apparatus by, for example, reading out and executing the computer executable instructions from the storage medium to perform the functions of one or more of the above-described embodiment(s). The computer may comprise one or more of a central processing unit (CPU), micro processing unit (MPU), or other circuitry, and may include a network of separate computers or separate computer processors. The computer executable instructions may be provided to the computer, for example, from a network or the storage medium. The storage medium may include, for example, one or more of a hard disk, a random-access memory (RAM), a read only memory (ROM), a storage of distributed computing systems, an optical disk (such as a compact disc (CD), digital versatile disc (DVD), or Blu-ray Disc (BD)™), a flash memory device, a memory card, and the like.

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application No. 2012-136391, filed on Jun. 15, 2012, which is hereby incorporated by reference herein in its entirety.

What is claimed is:

1. An image recording apparatus comprising:

at least one processor that functions as:

an obtaining unit configured to obtain image data which can generate a refocus image, and photographing information of the image data, wherein the refocus image is at a refocus plane including a virtual image pickup plane;

a parameter generation unit configured to generate a parameter which is used to calculate a refocus image at the refocus plane, based on the photographing information obtained by the obtaining unit; and

a recording unit configured to record the parameter generated by the parameter generation unit as meta data of the image data in a recording medium together with the image data obtained by the obtaining unit.

2. The image recording apparatus according to claim **1**, wherein the photographing information includes an iris value and a defocus map of the image data, and the parameter generation unit generates a conversion matrix, used to convert the image data obtained by the obtaining unit into a refocus image focusing on an object included in the image data, as the parameter based on the defocus map.

3. The image recording apparatus according to claim **1**, wherein the photographing information includes an iris value and a defocus map of the image data, and the parameter generation unit generates the parameter indicating a defocus amount of an object included in the image data, based on the defocus map.

4. The image recording apparatus according to claim **2**, wherein the parameter generation unit includes an object detection unit configured to detect the object included in the image data, based on the defocus map, and when the object detection unit detects a plurality of the objects, the parameter generation unit generates the conversion matrices used to convert the image data, obtained by the obtaining unit, into the refocus images of each of the plurality of objects, as the parameters in relation to each of the plurality of objects based on the defocus map.

5. The image recording apparatus according to claim **3**, wherein the parameter generation unit includes an object detection unit configured to detect the object based on the defocus map, and when the object detection unit detects a plurality of the objects, the parameter generation unit generates the parameters indicating the defocus amounts of each of the plurality of objects included in the image data, based on the defocus map in relation to each of the plurality of objects.

6. The image recording apparatus according to claim **1**, wherein the recording unit includes a priority determination unit configured to determine priorities of a plurality of objects included in the image data, and the recording unit records the parameters generated by the parameter generation unit as the meta data according to the priorities of the plurality of objects.

7. The image recording apparatus according to claim **6**, wherein the priority determination unit includes a face detection unit configured to detect a face from the image data, and when the face is detected, the priority determination unit sets a first place of the priority for the object including the face detected by the face detection unit.

8. An image reproducing apparatus for reproducing image data recorded by an image recording apparatus including an obtaining unit configured to obtain image data which can generate a refocus image, and photographing information of the image data, wherein the refocus image is at a refocus plane including a virtual image pickup plane; a parameter generation unit configured to generate a parameter which is used to calculate a refocus image at the refocus plane, based on the photographing information obtained by the obtaining unit; and a recording unit configured to record the parameter generated by the parameter generation unit as meta data of the image data in a recording medium together with the image data obtained by the obtaining unit, the image reproducing apparatus comprising:

a read unit configured to read out the image data recorded by the recording unit and the parameter from the recording medium;

a refocus image generation unit configured to generate the refocus image from the image data readout by the read unit using the parameter readout by the read unit; and

an editing unit configured to edit the refocus image generated by the refocus image generation unit according to an editing instruction, and to edit the parameter of the refocus image edited according to the editing instruction.

9. The image reproducing apparatus according to claim **8**, wherein the editing unit includes an instruction unit configured to instruct to change a refocus position and an iris value, and the refocus image generation unit generates the refocus image based on a change of the parameter instructed by the instruction unit.

10. The image reproducing apparatus according to claim **9**, further comprising a display unit configured to display the refocus image generated by the refocus image generation unit, and the instruction unit, wherein when a plurality of the parameters are read out by the read unit, the refocus image generation unit generates a plurality of the refocus images using each of the parameters, and the display unit displays the plurality of refocus images generated by the refocus image generation unit according to priorities of the plurality of parameters readout by the refocus image generation unit.

11. The image reproducing apparatus according to claim **10**, wherein the display unit displays the refocus image edited based on the changes of the parameters instructed by the instruction unit, together with the instruction unit.

12. The image reproducing apparatus according to claim **10**, wherein the editing unit includes a unit configured to perform a replacement or a deletion of the refocus image displayed by the display unit, and if the replacement of the deletion is performed, the editing unit changes the priority of the parameter corresponding to the refocus images edited by the editing unit according to the replacement or the deletion.

13. The image reproducing apparatus according to claim **8**, further comprising a recording unit configured to record the parameter edited by the editing unit as the meta data of the image data readout by the read unit, wherein the recording unit includes a priority setting unit configured to set a priority of the parameter of the image data edited by the editing unit, records the image data edited by the editing unit and the parameters according to the priority set by the priority setting unit, and changes the priority of other parameter recorded by the recording unit according to the setting.

14. An image pickup apparatus comprising:

an image pickup unit configured to photograph an image;

an image recording apparatus comprising:

an obtaining unit configured to obtain image data from the image pickup unit which can generate a refocus image, and photographing information of the image data, wherein the refocus image is at a refocus plane including a virtual image pickup plane;

a parameter generation unit configured to generate a parameter which is used to calculate a refocus image at a refocus plane , based on the photographing information obtained by the obtaining unit; and

a recording unit configured to record the parameter generated by the parameter generation unit as meta data of the image data in a recording medium together with the image data obtained by the obtaining unit;

an image reproducing apparatus for reproducing the image data recorded by the image recording apparatus, the image reproducing apparatus comprising:

a read unit configured to read out the image data recorded by the recording unit and the parameter from the recording medium;

a refocus image generation unit configured to generate the a refocus image from the image data readout by the read unit using the parameter readout by the read unit; and

an editing unit configured to edit the refocus image generated by the refocus image generation unit according to an editing instruction, and to edit the parameter of the refocus image edited according to the editing instruction; and

a control unit configured to control a photographing operation of the image pickup unit.

15. The image recording apparatus according to claim **1**, wherein the image data is photographed by an image pickup unit,

wherein the image pickup unit comprises:

a plurality of photoelectric conversion elements; and

an array of a plurality of microlenses which are arranged between a photographing lens and the photoelectric conversion elements, and one of which corresponds to an array of the predetermined number of photoelectric conversion elements.

16. An image recording method comprising:

an obtaining step of obtaining image data which can generate a refocus image, and photographing information of the image data, wherein the refocus image is at a refocus plane including a virtual image pickup plane;

a parameter generation step of generating a parameter which is used to calculate a refocus image at a refocus plane , based on the photographing information obtained in the obtaining step; and

a recording step of recording the parameter generated in the parameter generation step as meta data of the image data in a recording medium by a recording unit together with the image data obtained in the obtaining step.

17. An image reproducing method for reproducing image data recorded in a recording medium by an image recording method including an obtaining step of obtaining image data which can generate a refocus image, and photographing information of the image data, wherein the refocus image is at a refocus plane including a virtual image pickup plane; a parameter generation step of generating a parameter which is used to calculate a refocus image at a refocus plane, based on the photographing information obtained in the obtaining step; and a recording step of recording the parameter generated in the parameter generation step as meta data of the image data in a recording medium by a recording unit together with the image data obtained in the obtaining step, the image reproducing method comprising:

a read step of reading out the image data recorded in the recording medium and the parameter from the recording medium;

a refocus image generating step of generating the refocus image from the image data readout from the recording medium using the parameter readout from the recording medium; and

an editing step of editing the refocus image generated in the refocus image generating step according to an editing instruction by an instruction unit, and editing the parameter of the refocus image edited according to the editing instruction.

18. A non-transitory computer-readable storage medium storing a program comprising a program code for causing a computer to execute an image recording method including:

an obtaining step of obtaining image data which can generate a refocus image, and photographing information of the image data, wherein the refocus image is at a refocus plane including a virtual image pickup plane;

a parameter generation step of generating a parameter which is used to calculate a refocus image at a refocus plane, based on the photographing information obtained in the obtaining step; and

a recording step of recording the parameter generated in the parameter generation step as meta data of the image data in a recording medium by a recording unit together with the image data obtained in the obtaining step.

19. A non-transitory computer-readable storage medium storing a program comprising a program code for causing a computer to execute an image reproducing method for reproducing image data recorded in a recording medium by an image recording method including an obtaining step of obtaining image data which can generate a refocus image, and photographing information of the image data, wherein the refocus image is at a refocus plane including a virtual image pickup plane; a parameter generation step of generating a parameter which is used to calculate a refocus image at a refocus plane, based on the photographing information obtained in the obtaining step; and a recording step of recording the parameter generated in the parameter generation step as meta data of the image data in a recording medium by a recording unit together with the image data obtained in the obtaining step, the image reproducing method comprising:

a read step of reading out the image data recorded in the recording medium and the parameter from the recording medium;

a refocus image generating step of generating the refocus image from the image data readout from the recording medium using the parameter readout from the recording medium; and

an editing step of editing the refocus image generated in the refocus image generating step according to an editing instruction by an instruction unit, and editing the parameter of the refocus image edited according to the editing instruction.

20. The image recording apparatus according to claim **3**, wherein the defocus map is distribution information corresponding to positions, in a depth direction, on which each of a plurality of the objects included in the image data focuses.

21. The image recording apparatus according to claim **20**, wherein the defocus map is the distribution information of the defocus amount which is calculated based on a phase difference of a pair of signal data out of the image data.

22. The image recording apparatus according to claim **1**, wherein the refocus image is an image focusing on any one of a plurality focus positions including a focus position different from a focus position when the image data is photographed.

23. The image recording apparatus according to claim **1**, wherein the parameter is information corresponding to a focus position of the refocus image used to synthetic each pixel signal of the image data when the refocus image is generated.

24. The image recording apparatus according to claim **1**, wherein the parameter is information corresponding to a conversion matrix to be multiplied with each pixel signal of the image data when the refocus image is generated.

25. The image recording apparatus according to claim **1**, wherein the image data from which the refocus image can be generated is data including a plurality of pixel signals and angle information of light incident on pixels for obtaining the plurality of pixel signals.

26. An image recording apparatus comprising:

at least one processor that functions as:

an obtaining unit configured to obtain data output from an image pickup element on which predetermined number of pixels are arranged for each of a plurality of microlenses, and photographing information of the data;

a parameter generation unit configured to generate a parameter which is used to calculate, from the data output from the image pickup element, image data in which a focal plane of the image data is moved to a virtual focal plane, based on the photographing information obtained by the obtaining unit; and

a recording unit configured to record the parameter generated by the parameter generation unit as meta data of the data in a recording medium together with the data obtained by the obtaining unit.

27. An image recording method for recording, in a recording medium, data from which image data can be generated, comprising:

an obtaining step of obtaining data output from an image pickup element on which predetermined number of pixels are arranged for each of a plurality of microlenses, and photographing information of the data;

a parameter generation step of generating a parameter which is used to calculate, from the data output from the image pickup element, image data in in which a focal plane of the image data is moved to a virtual focal plane, based on the photographing information obtained by the obtaining unit; and

a recording step of recording the parameter generated in the parameter generation step as meta data of the data in a recording medium together with the data obtained by the obtaining unit.

28. A non-transitory computer-readable storage medium storing a program comprising a program code for causing a computer to execute an image recording method for recording, in a recording medium, data from which image data can be generated, including:

an obtaining step of obtaining data output from an image pickup element on which predetermined number of pixels are arranged for each of a plurality of microlenses, and photographing information of the data;

a parameter generation step of generating a parameter which is used to calculate, from the data output from the image pickup element, image data in which a focal plane of the image data is moved to a virtual focal plane, based on the photographing information obtained by the obtaining unit; and

a recording step of recording the parameter generated in the parameter generation step as meta data of the data in a recording medium together with the data obtained by the obtaining unit.

29. The image recording apparatus according to claim **1**, wherein the parameter generation unit generates the parameter corresponding to the refocus plane of the refocus image at which an object included in the image data is focused.

30. The image recording apparatus according to claim **1**, each of the parameters has a priority between the parameters.

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